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Technical Report S-155

# TEMPERATURE DEPENDENCE OF CARD-GAP SENSITIVITY AND FAILURE DIAMETER (U)

by

M. J. Pandow

November 1967

U. S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

Contract DA-01-021 AMC-15414(Z)

**ROHM AND HAAS COMPANY**
**REDSTONE RESEARCH LABORATORIES**
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REDSTONE RESEARCH LABORATORIES

HUNTSVILLE, ALABAMA 35807

# (C) FOREWORD

This work was performed under Contract DA-01-021 AMC-15414(Z) for propagation of stress waves in propellants under the technical cognizance of the Propulsion Mechanics Branch, Army Propulsion Laboratory and Center, Research and Development Directorate, U. S. Army Missile Command, and is in support of Defense Atomic Support Agency Nuclear Weapons Effects Research Subtask 15.045.

This report, together with Rohm and Haas Company Technical Report S-146, comprise a final technical report under this contract.

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## Section I. (U) INTRODUCTION

Various tests have been devised to assess the potential hazard involved in the use of explosive materials. Two of these are the card-gap test, which measures the minimum shock strength necessary to initiate detonation in a sample, and the failure-diameter test, which measures the smallest diameter for which detonation will propagate in a cylindrical charge. These tests are usually made at ambient temperature conditions (ca. 70 to 80°F). Since explosive materials are frequently stored and handled at temperatures above or below this, it is of interest to determine the effect of temperature changes on card-gap sensitivity and failure diameter. The effect of thermal stimulus on these properties is also of interest.

Some previous work had been done at these Laboratories (1, 2) on the effect of temperature on the card-gap sensitivities and failure diameters of some plastisol-nitrocellulose propellants in the temperature range from -40° to 140°F. In some cases only the failure diameter had been measured, and in others only card gap. Some of the propellants contained RDX additive.

The present work was undertaken to extend the temperature range to 200°F for both card-gap and failure diameter. In addition to the plastisol-nitrocellulose formulation, another type of propellant, polybutadiene-acrylic acid, has been studied.

## Section II. (C) RESULTS OF PREVIOUS EXPERIMENTS

(C) Failure diameters were measured for a series of plastisol-nitrocellulose propellants including RH-P-116 and this propellant with varying amounts of RDX (2 to 20%) replacing part of the ammonium perchlorate (1). (Formulations are given in Table I.) Measurements were made at three temperatures for each of five propellants: -60° to -50°F, ambient temperature, and 140°F (Table II). In these tests, the donors were C-4 with diameters matching those of the test samples. The failure diameter of RH-P-116 decreased by about ½ inch when the temperature was increased from 48° to 140°F. There was little or no change in the failure diameters of the RDX-containing propellants.

Table I. (C) Formulations Used in Previous Temperature Studies

| Designation | Double-Base Powder | TMETN | TEGDN | AP | Al | RDX | Resorcinol |
|---|---|---|---|---|---|---|---|
| RH-P-116 | 16.67 | | 32.33 | 30.00 | 20.00 | | 1.00 |
| RH-P-135 | 16.67 | | 32.33 | 20.00 | 20.00 | 10.00 | 1.00 |
| RH-P-144 | 16.67 | | 32.33 | 28.00 | 20.00 | 2.00 | 1.00 |
| RH-P-145 | 16.67 | | 32.33 | 25.00 | 20.00 | 5.00 | 1.00 |
| RH-P-146 | 16.67 | | 32.33 | 10.00 | 20.00 | 20.00 | 1.00 |
| RH-P-112 | 16.67 | | 37.33 | 30.00 | 15.00 | | 1.00 |
| RH-P-197 | 10.00 | 24.00 | 8.00 | 10.00 | 18.00 | 28.00 | 1.00 |

(U) Card gaps were measured for two of the formulations, RH-P-116, and the formulation containing 10% RDX (RH-P-135) (Table III). C-4 donors and cardboard cards, matched in diameter to the acceptors, were used. The card gap increased by 28 cards per 100F°. for RH-P-116; there was little change in card gap for the RDX-containing formulation.

(U) These trends in card gap were confirmed in a later series of experiments on RH-P-112 and RH-P-197 (2) (Table IV). The gaps were measured in the standard card-gap test (see Section III for description of test) and the Rohm and Haas small-scale card-gap test (3). The small-scale test uses the same donor—gap arrangement as the standard test, but a smaller sample size. An increase in card gap of 23 cards/100 F° is observed for RH-P-112. This is equivalent to an initiation pressure decrease of 21 kbar per 100 F°. The pressures were obtained from the U. S. Naval Ordnance Laboratories calibration of the standard gap test (4). No change was observed for the RDX-containing formulation, RH-P-197.

Table II. (U) Failure-Diameter Data for RH-P-116 and RDX-Containing RH-P-116 as a Function of Temperature

(Matched C-4 donor, hand-packed, $\rho$ = 1.59 gm/cc, L/D = 3)

| Formulation | % RDX | Temp. (°F) | $D_f$ (in.) |
|---|---|---|---|
| RH-P-116 | 0 | -48 | 1.38-1.61 |
| RH-P-116 | 0 | 82 | 1.05-1.38 |
| RH-P-116 | 0 | 140 | 0.82-1.05 |
| RH-P-144 | 2 | -65 | 1.05-1.38 |
| RH-P-144 | 2 | 77 | 0.82-1.05 |
| RH-P-144 | 2 | 140 | 0.82-1.05 |
| RH-P-145 | 5 | -48 | 0.82-1.05 |
| RH-P-145 | 5 | 82 | 0.62-0.82 |
| RH-P-145 | 5 | 140 | 0.62-0.82 |
| RH-P-135 | 10 | -48 | 0.36-0.82 |
| RH-P-135 | 10 | 82 | 0.36-0.82 |
| RH-P-135 | 10 | 140 | 0.36-0.82 |
| RH-P-146 | 20 | -61 | <0.36 |
| RH-P-146 | 20 | 73 | <0.36 |
| RH-P-146 | 20 | 140 | <0.36 |

Table III. (U) Card-Gap Values of RH-P-116 and RH-P-135 as a Function of Temperature

(Cardboard cards; matched C-4 donor, hand-packed, $\rho$ = 1.59 gm/cc, L/D = 3)

| Formulation | Temp. (°F) | Gap (Cards) |
|---|---|---|
| 1.61-in.-Diam. Acceptor | | |
| RH-P-116 | -42 | 32 |
| RH-P-116 | 83 | 67 |
| RH-P-116 | 135 | 82 |
| 1.05-in.-Diam. Acceptors | | |
| RH-P-135 | -36 | 47 |
| RH-P-135 | 86 | 57 |
| RH-P-135 | 105 | 57 |

| Table IV. (U) Card Gaps of RH-P-112 and RH-P-197 as a Function of Temperature | | | | |
|---|---|---|---|---|
| Formulation | Temp. (°F) | Test | Card Gap (in.) | Initiation Pressure (kbar) |
| RH-P-112 | -42 | Standard | 0.35-0.40 | 110 |
| RH-P-112 | 140 | Standard | 0.76-0.80 | 67 |
| RH-P-112 | -42 | Small-Scale | 0.48-0.50 | 96 |
| RH-P-112 | ca 85 | Small-Scale | 0.74-0.76 | 70 |
| RH-P-112 | 130 | Small-Scale | 0.86-0.88 | 60 |
| RH-P-197 | -42 | Small-Scale | 1.28-1.30 | 38 |
| RH-P-197 | ca 95 | Small-Scale | 1.28-1.30 | 38 |
| RH-P-197 | 130 | Small-Scale | 1.28-1.30 | 38 |

## Section III. (C) EXPERIMENTAL PROCEDURE

(C) The measurements on RH-P-112 were repeated and an additional measurement was made at 200°F. Measurements were made on RH-B-16 at approximately the same temperatures. (See Table V for formulations.)

Table V. (C) Formulations Used in Current Temperature Studies

| Designation | Double-Base Powder | TEGDN | AP | Al | Resorcinol |
|---|---|---|---|---|---|
| RH-P-112 | 16.67 | 37.33 | 30.00 | 15.00 | 1.00 |

| Designation | PBAA/ERL 2774 | AP | Al | RDX |
|---|---|---|---|---|
| RH-B-16 | 21.2 | 53.2 | 10.6 | 15.0 |

(U) Failure diameters and card gaps were measured in the set-up shown in Figure 1. The samples were placed in ice cream cartons of $3\frac{1}{4}$-inch diameter, 6 inches long. The space between the sample and the walls of the carton was filled with granulated asbestos. The samples in the cartons were conditioned at the desired temperature for a length of time sufficient to insure temperature equilibrium throughout the sample. Four temperatures, ranging from -40° to 200°F, were used. Sheets of transite were placed over the ends of the 200°F samples during conditioning and were removed immediately before firing. The samples were fired approximately four minutes after removal from the oven.

(U) The failure-diameter samples varied in diameter from 0.62 inch to 1.61 inches. All were 6 inches long except the 1.61-inch-sample, which was $6\frac{1}{4}$ inches long. The card-gap samples were the size listed in the standard test, TB 700-2(5): 1.437 inches inside diameter, 6 inches long, steel confined. All samples were initiated with two pentolite pellets, each 2 inches in diameter by one inch thick. The pentolite was initiated by an electric blasting cap, J2. The minimum donor diameter necessary to initiate a supercritical charge was determined for RH-P-112 as a function of temperature. This was done by initiating charges with diameters greater than critical with C-4 donors of varying diameters with a L/D ratio of at least three. The C-4 donors were hand-packed to a density of 1.59 gm/cc.

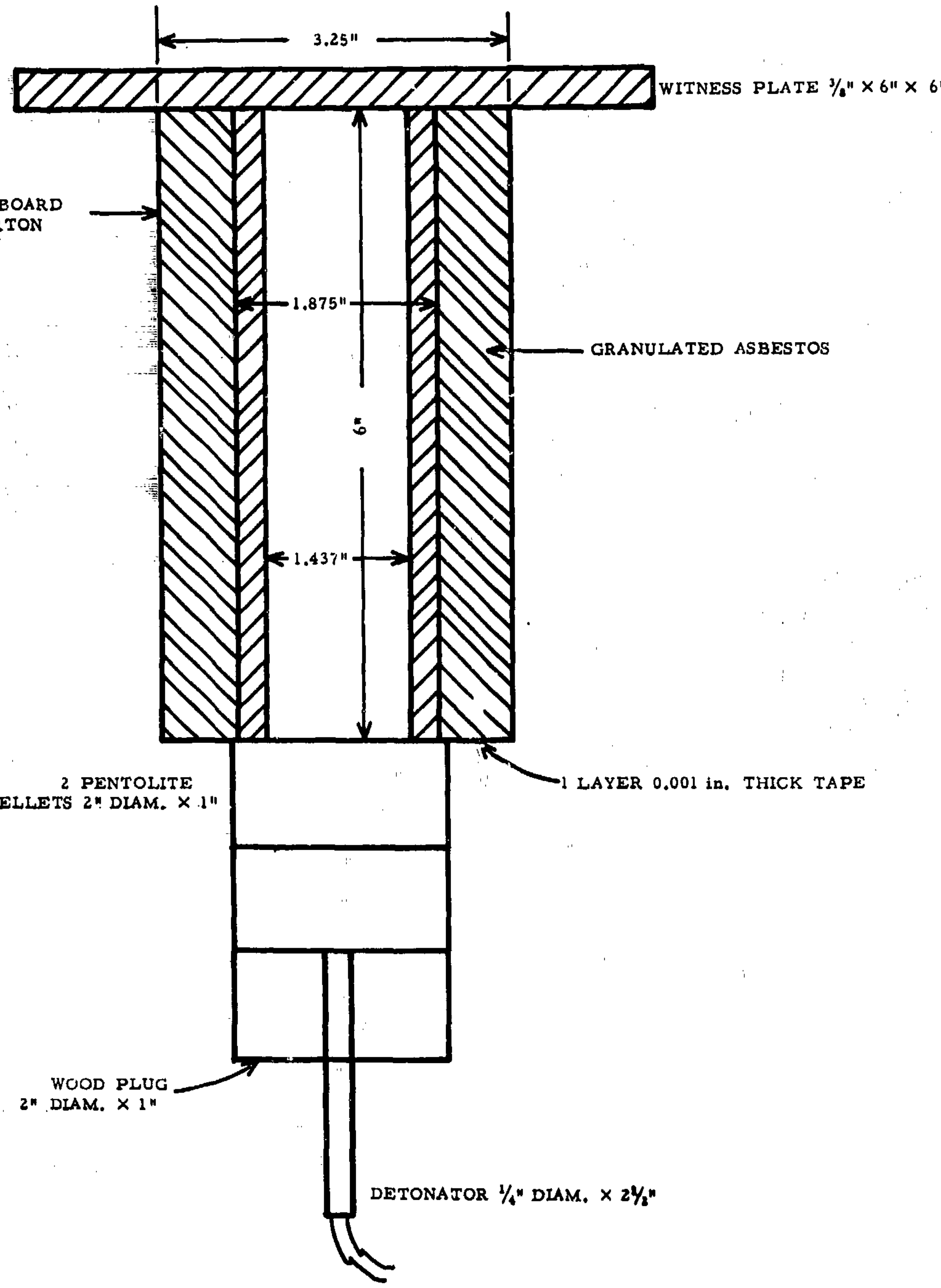


FIGURE 1. (U) FIRING ARRANGEMENT FOR FAILURE DIAMETER AND CARD-GAP TESTS.

(U) A heating curve was obtained for the 200°F samples to ascertain how long the samples must be conditioned to attain the proper temperature. Iron-constantan thermocouples were inserted in the end of each sample to a depth of $^3/_8$ inch and the entire assemblage placed in the oven. Temperatures were measured at half-hour intervals over a period of two hours (Table VI). At the end of two hours the samples had reached a temperature of 200°F. In Figure 2 the heating rate is compared with theoretically calculated curves (6) for heating in an oven with still air and in one with moderate air motion. Since there was forced-air motion in the heating oven, the experimental heating rate should be more nearly like the curve for an oven with moderate air motion. The agreement is reasonably good for a rough approximation.

Table VI. (U) Heating Rate for Propellant Sample in 200° Oven

| Time in Oven (hr.) | Temperature of Sample (°F) |
|---|---|
| 0 | 75 |
| ½ | 120 |
| 1 | 159 |
| 1½ | 187 |
| 2 | 200 |

(U) Cooling data were obtained for 220° and 146°F samples (Tables VI and VIII). In the 4 minutes between removal from the oven and firing, a sample heated to 220°F would cool to 201°F and a sample heated to 146°F would cool to 140°F.

Table VII. (U) Cooling Rate for Sample Heated to 220°F (Outside Temp. 46°F)

| Time (min.) | Temperature of Sample (°F) |
|---|---|
| 0 | 220 |
| 1 | 216 |
| 2 | 212 |
| 3 | 207 |
| 4 | 201 |

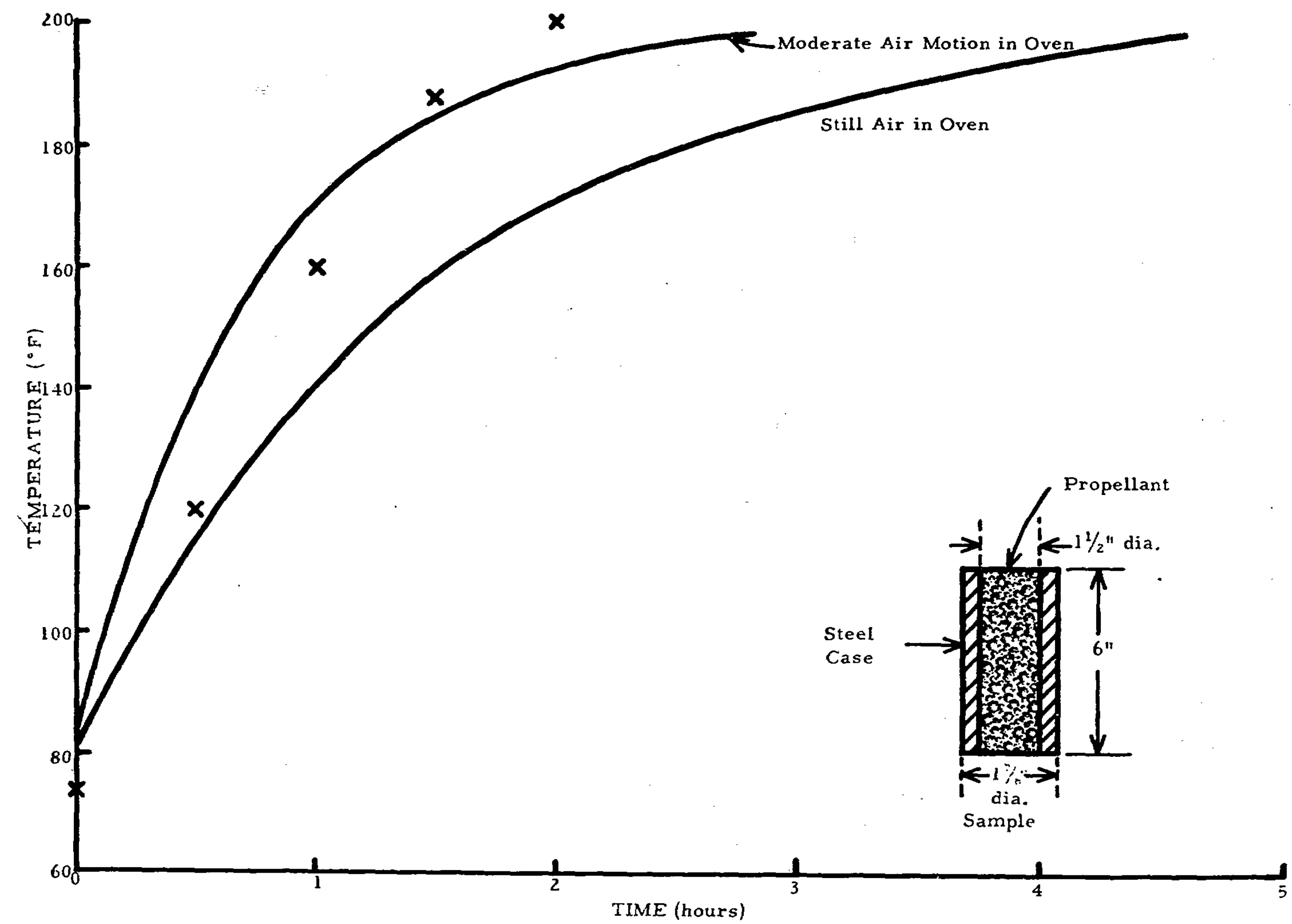


FIGURE 2. (U) THERMAL RESPONSE OF SAMPLE IN 200° OVEN.

Table VIII. (U) Cooling Rate for Sample Heated to 146°F (Outside Temp. 30°F)

| Time (min.) | Temperature of Sample (°F) |
|---|---|
| 0 | 146 |
| 1 | 144 |
| 2 | 142 |
| 3 | 142 |
| 4 | 140 |
| 5 | 139 |

The failure diameter, $D_f$, of RH-P-112 decreases linearly over the temperature range from -40°F to 200°F (Table IX and Figure 3). The decrease amounts to 0.26 inch/100 F°. The minimum donor diameter for this same formulation decreases by the same amount. The failure diameter of RH-B-16 (Table IX and Figure 3) does not change over this same temperature range. The apparent slight increase in the failure diameter at 200°F is probably due to experimental error. Minimum donor diameters were not obtained for this formulation.

Table IX. (U) Temperature Dependence of Failure Diameter

| Formulation | Temperature (°F) | $D_f$ (in.) | $D_i$ (in.) |
|---|---|---|---|
| RH-P-112 | -39 | 1.25-1.38 | 1.15-1.25 |
| RH-P-112 | 72 | 0.82-1.00 | 0.82-1.00 |
| RH-P-112 | 146 | 0.82-1.00 | 0.62-0.75 |
| RH-P-112 | 200 | 0.62-0.75 | 0.50-0.62 |
| RH-B-16 | -40 | 1.38-1.50 | |
| RH-B-16 | 74 | 1.38-1.50 | |
| RH-B-16 | 160 | 1.50-1.61 | |
| RH-B-16 | 200 | 1.50-1.61 | |

The card gap of RH-P-112 increases linearly from 72° to 200°F (Table X and Figure 4). From -40° to 72°F the increase is slightly greater than on the linear portion of the curve. An average value of the increase over the entire temperature range of 240 F° is 0.23 in/100 F°. This agrees with previous work on the same propellant (2). Comparison of values in Table IV for the standard test on RH-P-112 with present results shows good agreement between the actual gap values. Conversion of the gap values to initiation pressure (Table X and Figure 5) gives a nonlinear curve with a sharper decrease at lower temperatures. The overall decrease in pressure in the temperature range studied is 59 kbar.

The gap values for RH-B-16 (Table X and Figure 4) are essentially constant from 76° to 200°F and lower gap values are exhibited at -40°F. The initiation pressures (Table X and Figure 5) are constant from 76° to 200°F and exhibit a slight increase at -40°F. All previous studies on propellants containing RDX (1, 2) showed the same type of

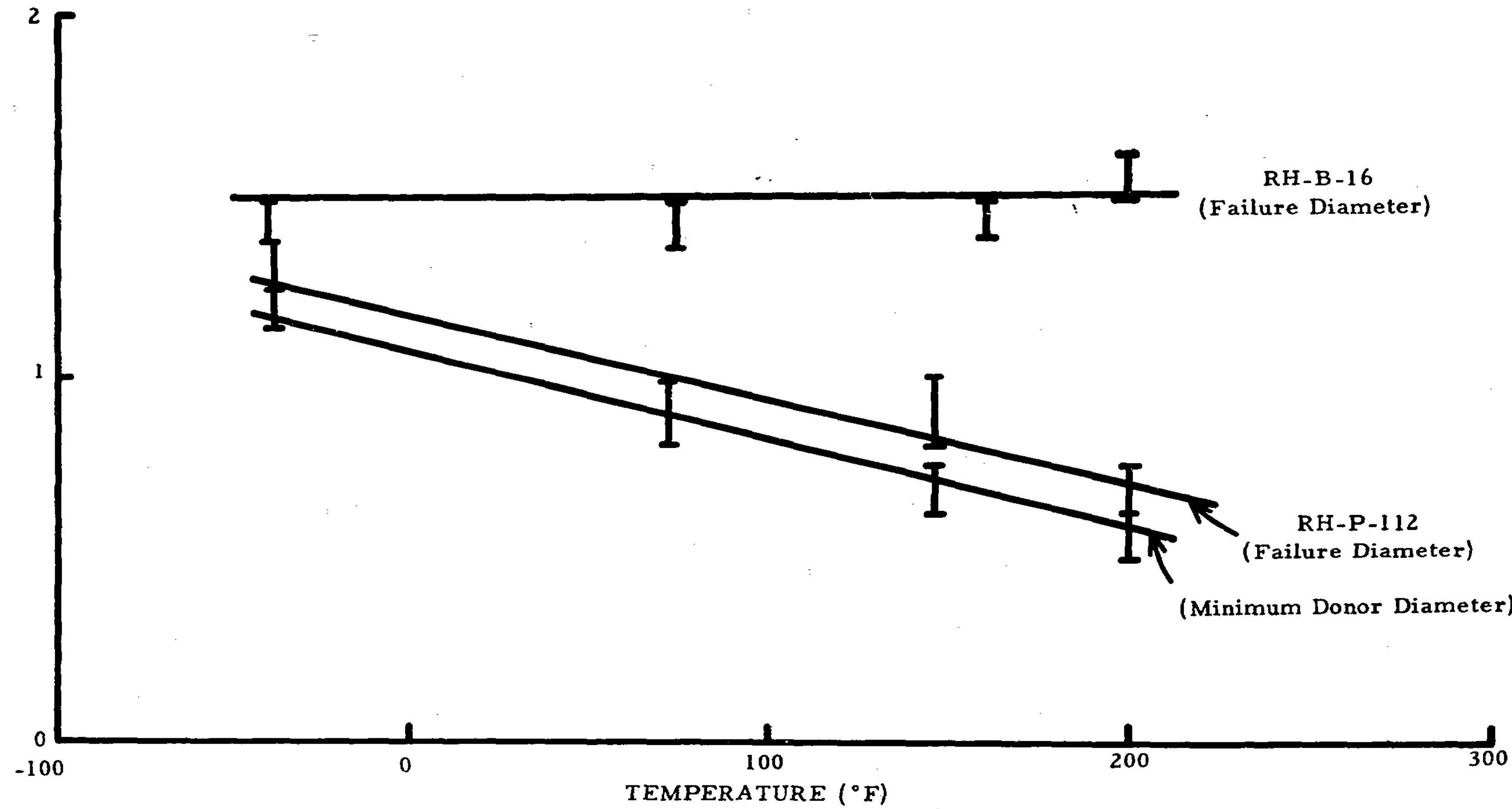


FIGURE 3. (U) TEMPERATURE DEPENDENCE OF FAILURE DIAMETER

behavior. Since the previous studies were on plastisol-nitrocellulose-based propellants and the present work uses polybutadiene-acrylic acid-based propellants, it can be concluded that RDX-containing propellants exhibit little or no change in card-gap sensitivity and failure diameter with temperature.

Table X. (U) Temperature Dependence of Card Gap

| Formulation | Temperature (°F) | Card Gap (in.) | Initiation Pressure (kbar) |
|---|---|---|---|
| RH-P-112 | -39 | 0.30-0.32 | 121 |
| RH-P-112 | 72 | 0.62-0.64 | 82 |
| RH-P-112 | 146 | 0.75-0.77 | 69 |
| RH-P-112 | 200 | 0.84-0.86 | 62 |
| RH-B-16 | -40 | 1.22-1.24 | 41 |
| RH-B-16 | 77 | 1.39-1.41 | 33 |
| RH-B-16 | 160 | 1.37-1.39 | 34 |
| RH-B-16 | 200 | 1.37-1.39 | 34 |

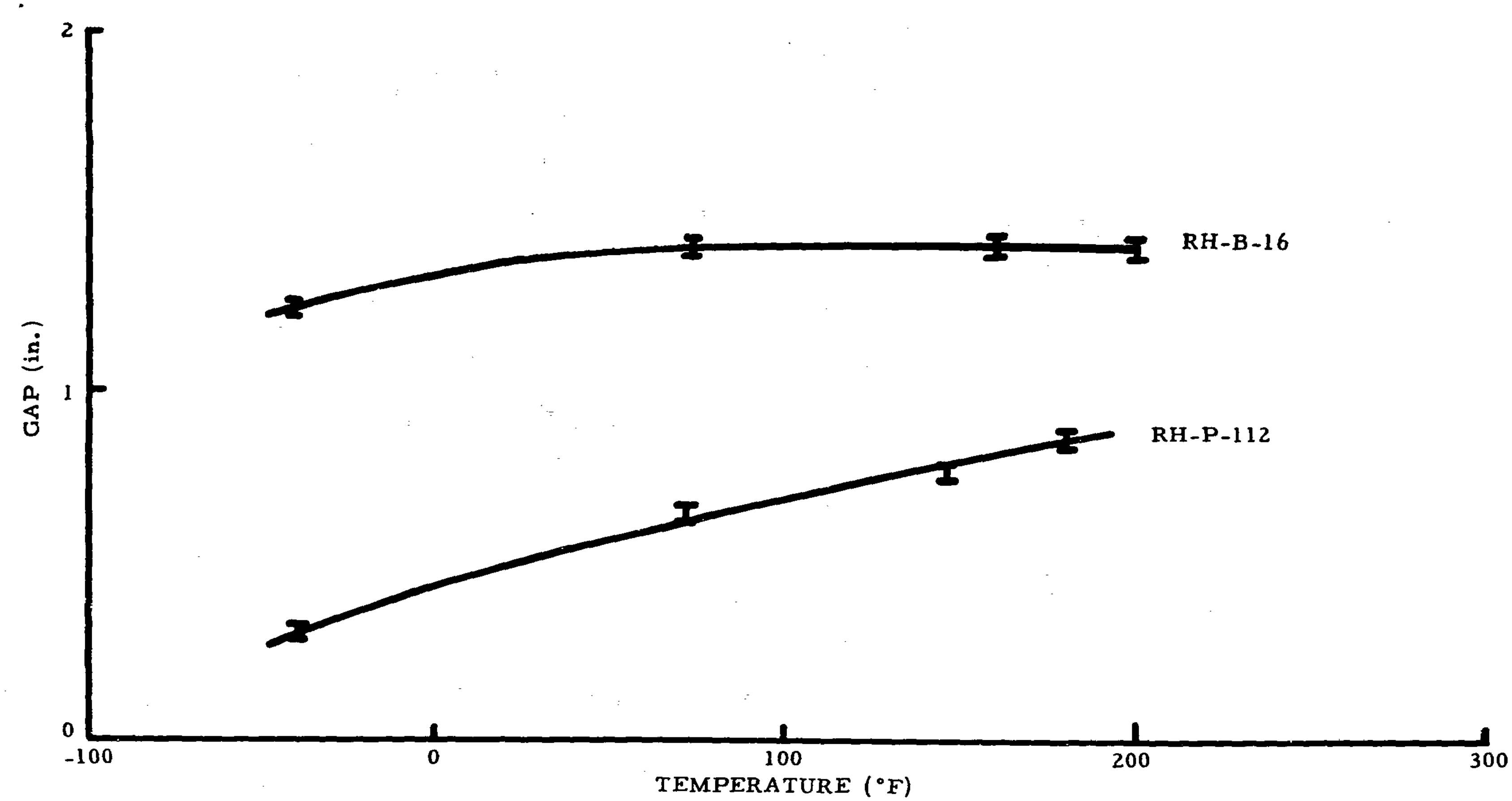


FIGURE 4 (U) TEMPERATURE DEPENDENCE OF CARD GAP.

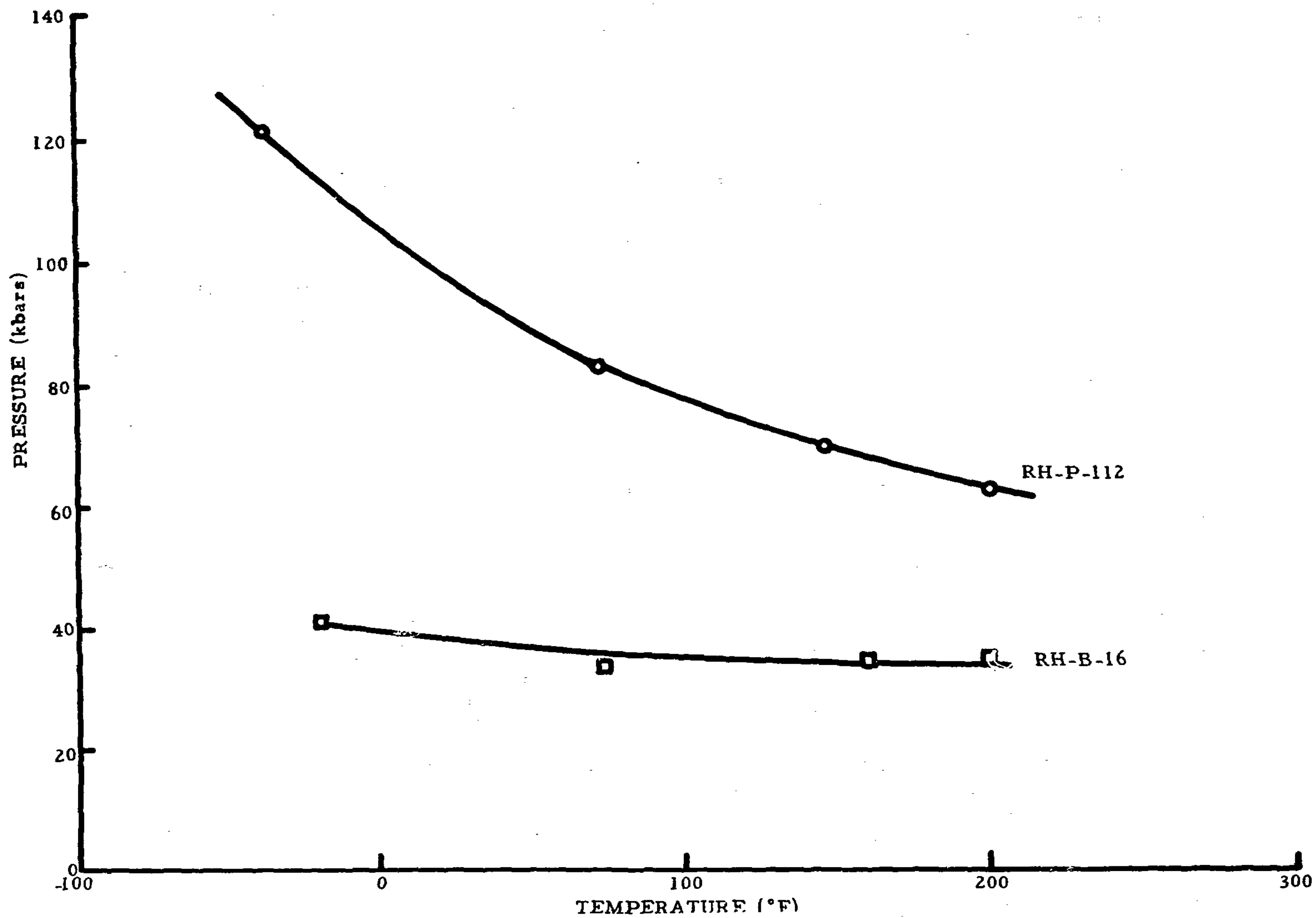


FIGURE 5. (U) TEMPERATURE DEPENDENCE OF INITIATION PRESSURE.

## Section V. (U) CONCLUSIONS

1. Card-gap sensitivities of plastisol-nitrocellulose propellants which do not contain RDX increase with increasing temperature. Initiation pressures decrease.

2. Failure diameters of plastisol-nitrocellulose propellants which do not contain RDX decrease linearly with increasing temperature.

3. Card-gap sensitivities of plastisol-nitrocellulose and polybutadiene-acrylic acid propellants containing RDX show little or no change with changing temperature.

4. Failure diameters of plastisol-nitrocellulose and polybutadiene-acrylic acid propellants containing RDX show little or no change with changing temperature.

## (U) REFERENCES

1. Rohm and Haas Co., Huntsville, Alabama, QUARTERLY PROGRESS REPORT ON INTERIOR BALLISTICS (U), January 27, 1961, Report P-60-19, p. 6, U. S. Army Missile Command, Redstone Arsenal, Alabama 35809, Contracts DA-01-021 ORD-778(Z) and DA-01-021 ORD-11878(Z), (Confidential).

   Ibid., October 3, 1961, P-61-7, Contracts DA-01-021 ORD-778(Z), DA-01-021 ORD-11909(Z), and DA-01-021 ORD-12024(Z).

2. Private communication with T. H. Pratt.

3. Rohm and Haas Co., Huntsville, Alabama, THE EXPLOSIVE CHARACTERISTICS OF NF COMPOUNDS AND PROPELLANTS, T. H. Pratt, October 8, 1964, Report S-79, p. 3, U. S. Army Missile Command, Redstone Arsenal, Alabama 35809, Contracts DA-01-021 ORD-11,878(Z), DA-01-021 ORD-11,909(Z), and DA-01-021 AMC-11,536(Z) (Confidential). AD-366 209.

4. United States Naval Ordnance Laboratory, White Oak, Maryland, RECALIBRATION OF THE STANDARD GAP TEST, 20 August 1965, NOLTR 65-43, T. P. Liddiardl Jr., and Donna Price (Unclassified).

5. Dept. of the Army Technical Bulletin, TB-700-2, EXPLOSIVE HAZARD CLASSIFICATION PROCEDURE, p. 13 (Unclassified).

6. Private communication with Donald A. Willoughby.

## (C) GLOSSARY

| | |
|---|---|
| AP | Ammonium perchlorate |
| Al | Aluminum |
| PBAA | Polybutadiene-acrylic acid copolymer |
| PNC | Plastisol nitrocellulose |
| RDX | Hexahydro-1, 3, 5-trinitro-s-triazine |
| TEGDN | Triethylene glycol dinitrate |
| TMETN | 1, 1, 1-trimethylolethane trinitrate |
| ERL | A trifunctional epoxy cure agent supplied by Union Carbide Company. |

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3. REPORT TITLE

Temperature Dependence of Card-Gap Sensitivity and Failure Diameter

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Mary L. Pandow

| | | |
|---|---|---|
| 6. REPORT DATE<br>November 1967 | 7a. TOTAL NO. OF PAGES<br>19 | 7b. NO. OF REFS<br>6 |
| 8a. CONTRACT OR GRANT NO.<br>DA-01-021 AMC-15414(Z)<br>b. PROJECT NO.<br>c.<br>d. | 9a. ORIGINATOR'S REPORT NUMBER(S)<br>Technical Report S-155<br>9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) | |

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13. ABSTRACT

The temperature dependence of card-gap sensitivity and failure diameter of a plastisol-nitrocellulose propellant and a polybutadiene propellant containing RDX have been determined. The card-gap sensitivity increased and the failure diameter decreased for the PNC propellant. Neither of these values showed much change, if any, for the RDX-containing PBAA formulation. These results agree with those previously obtained at these Laboratories.

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Temperature dependence | | | | | | |
| Card gap sensitivity | | | | | | |
| Failure diameter | | | | | | |
| Propellants | | | | | | |
| PBAA | | | | | | |
| Plastisol nitrocellulose | | | | | | |
| RDX | | | | | | |